STATE OF WASHINGTON
INDEPENDENT SCIENCE PANEL

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August 31, 2006

The Honorable Christine Gregoire
Governor of Washington
PO Box 40002
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The Honorable Lisa Brown
Majority Leader of the Senate
PO Box 40403
Olympia, WA 98504-0403

The Honorable Frank Chopp
Speaker of the House
PO Box 40600
Olympia, WA 98504-0600

Dear Governor Gregoire, Senator Brown and Representative Chopp:

The Independent Science Panel (ISP) was created by the Legislature in 1998 to provide scientific review and oversight, and help ensure that sound science is used in Washington's salmon, steelhead, and trout recovery efforts (77.85.040 RCW). The ISP's findings are to be provided periodically to the Governor and the Legislature.

In a memo dated April 7, 2006 the Governor's Salmon Recovery Office asked us to review the draft "*Study Plan for the Intensively Monitored Watershed Program,"* and respond to a series of questions related to the plan's technical strengths, shortcomings, and opportunities for improvement.

In June 2003, the Salmon Recovery Funding Board (SRFB) initiated funding of an Intensively Monitored Watershed (IMW) program to evaluate whether habitat restoration projects and activities done over a whole watershed would affect an increase in the abundance of out-migrating juvenile salmon.

Creating one or more IMWs in Washington to determine the response of salmon populations to habitat restoration was a key recommendation of *The Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery*, which was requested by the Legislature in 2001. The recommendation was intended to address an important policy and scientific question: "How can we be confident that habitat restoration projects will be effective in increasing salmon populations?"

After a detailed review, we find that the draft IMW study plan is designed as a comprehensive effort that could represent the beginning of a state-of-the-art intensive monitoring program to test and validate salmon habitat restoration strategies at the watershed scale. The strengths of the draft plan are its solid scientific conceptual framework, fundamentally robust study designs, and a well-qualified interagency team of scientists working to develop and refine the experimental designs and implement the monitoring. Given the opportunities currently available for initiating IMWs, the choices of species and watersheds/complexes seem appropriate.

Notwithstanding those strengths however, some unresolved issues and a lack of information in the draft study plan hamper our ability to offer a definitive conclusion about how well the program will be able to meet its objectives. Serious weaknesses include the apparent disconnect between how treatments (i.e., the restoration actions) are selected and funded in relation to experimental design and IMW monitoring needs, and uncertainty about the duration of the commitment to fund the long-term nature of the IMW program. In addition, information on data management, standards, and quality assurance was not included in the draft plan, nor was it clear how results of IMW work are intended to guide in decision-making processes.

Although much more detail is included in our report, we below summarize four groups of key recommendations below that if addressed, in conjunction with the points discussed above, should significantly improve the likelihood that the IMW program will achieve its objectives:

1. Develop specific, detailed study plans for each study component and IMW complex, including statistical power analysis and other aspects related to the individual project objectives. To improve the ability to test and generalize about the efficacy of habitat restoration approaches, work cooperatively to develop and implement meta-analyses by coupling the results of the SRFB-funded IMW program with other IMW efforts in Washington and across the Pacific Northwest. Describe organization structures that will meet the program's objectives.

2. Clarify expectations about what to expect from generalizing results from results the IMW plan to other watersheds. The most immediate importance of the IMW work may be to provide a valuable series of case studies from which qualitative generalizations can be applied to other areas.

3. Develop mechanisms to ensure coordination of restoration actions within IMW complexes that are appropriately chosen and implemented at a large enough scale to be able to detect a response or lack of response consistent with the experimental design.

4. Support the collaborations that already exist between the SRFB-funded IMW program and similar efforts funded by other agencies in the Pacific Northwest and expand this collaboration.

The results of this review are contained in our report "*Review of Study Plan for the Intensively Monitored Watershed Program" (April 26, 2006 review draft)* (ISP Report 2006-1) (enclosed). Copies of the report have been provided to the Governor's Salmon Recovery Office, the Salmon Recovery Funding Board, the Governor's Forum on Monitoring Salmon Recovery and Watershed Health, and the authors of the IMW study plan.

We are optimistic that our comments on the SRFB-funded IMW program will also inform IMW efforts funded by other entities, and that the growing interest in IMWs across the Pacific Northwest will contribute substantively toward improved understanding of how investments in habitat restoration actions benefit salmon and their recovery for the citizens of Washington State.

As always, we hope our work will be of value to you in your continuing efforts toward salmon recovery and watershed health.

Please contact us if you have questions about any aspect of these comments.

Sincerely,

Kenneth P. Currens, Chair

Enclosure

cc: Senator Ken Jacobsen, Chair, Senate Natural Resources, Ocean & Recreation Committee
Representative Brian Sullivan, Chair, House Natural Resources, Ecology & Parks Committee
Mr. William Ruckelshaus, Chair, Salmon Recovery Funding Board

Independent Science Panel
Report 2006-1
August 31, 2006

Review of "Study Plan for the Intensively Monitored Watershed Program" (April 26, 2006 review draft)

Independent Science Panel
PO Box 43135
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Executive Summary

Intensive monitoring of one or more watersheds in Washington to determine the response of salmon populations to habitat improvement was a key recommendation of *The Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery*, which was requested by the Legislature in 2001. The recommendation was intended to address an important policy and scientific question: "How can we be confident that habitat improvement projects will be effective in increasing salmon populations?"

In June 2003, the Salmon Recovery Funding Board (SRFB) funded the Intensively Monitored Watershed (IMW) program to evaluate whether habitat improvement projects done over a whole watershed could increase the abundance of out-migrating juvenile salmon. In April 2006, the Governor's Salmon Recovery Office asked the Independent Science Panel (ISP) to review the draft "Study plan for the Intensively Monitored Watershed Program" (April 26, 2006 review draft) and respond to a series of questions about the plan's technical strengths, shortcomings, and opportunities for improvement.

The draft IMW study plan focuses on monitoring the effectiveness of habitat improvement in four watershed complexes in western Washington. It has three components: (1) evaluating the effects of freshwater habitat actions on production of juvenile coho salmon, steelhead, and cutthroat trout in three complexes of small watersheds flowing into the Strait of Juan de Fuca on the Olympic Peninsula, the Hood Canal, and the lower Columbia River; (2) evaluating the effects of estuary restoration on growth and survival of juvenile Chinook salmon in the Skagit River estuary; and (3) developing a Pacific Northwest-wide watershed classification, which is intended to guide the application of SRFB-funded IMW results to other watersheds.

Based on the information reviewed, the ISP concludes that the IMW program is designed as a comprehensive watershed scale effort that could represent the beginning of a state-of-the-art intensive monitoring program to test and validate contemporary salmon habitat improvement strategies at the watershed scale. The strengths of the draft plan are its solid scientific conceptual framework, fundamentally robust study design, and well-qualified, interagency team of scientists to design and implement the monitoring. Given the opportunities currently available for initiating IMWs, the choices of species and watersheds/complexes seem appropriate.

Notwithstanding those strengths however, some unresolved issues and lack of information in the draft study plan hamper the ISP's ability to offer a definitive conclusion about how well the program will be able to meet its objectives. Serious weaknesses include an apparent disconnect between how treatments (i.e., the habitat improvement actions) are selected and funded, in relation to experimental design and monitoring needs, and uncertainty about the duration of the commitment to fund the long-term nature of the IMW program. In addition, information on data management, standards, and quality assurance was not included in the draft plan, nor was it clear how results from IMW work are intended to guide decision-making.

In addition to the above concerns, below is a summary of four groups of key recommendations that if addressed, should significantly improve the likelihood that the IMW program will achieve its stated objectives:

1. Develop specific, detailed study plans for each plan component and IMW complex, including power analysis and other statistical aspects pertaining to the statistical rigor needed to achieve individual project objectives. To improve the ability to test and generalize about the efficacy of habitat improvement approaches, work cooperatively to develop and implement meta-analyses by coupling the results of the SRFB-funded IMW program with other IMW efforts in Washington and across the Pacific Northwest. Describe an organizational structure that will meet the program's objectives.

2. Clarify what to expect from generalizing results from the IMW program to other watersheds. The most immediate importance of the IMW work may be to provide a valuable series of case studies from which qualitative generalizations can be applied to other areas.

3. Develop mechanisms to ensure coordination of improvement actions within identified IMW complexes are appropriately chosen and implemented at a large enough scale to be able to detect a response or lack of response consistent with the experimental design.

4. Support the collaborations that already exist between this SRFB-funded IMW program and similar efforts funded by other agencies in the Pacific Northwest and expand this collaboration.

Introduction

Purpose

Creating one or more intensively monitored watersheds (IMWs) in Washington to determine the response of salmon populations to habitat improvement in addition to implementing other types of monitoring (e.g., implementation, status and trend, project or reach-scale effectiveness monitoring) was a key recommendation of *The Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery*, requested by the Legislature in 2001.[1] The recommendation was intended to address an important policy and scientific question, "How can we be confident that habitat improvement projects will be effective in rebuilding salmon populations?" Habitat improvement was expected to be expensive. Politically, these expenses are perceived to reduce funds available to meet other needs (e.g., habitat projects or other conservation actions). Scientifically, the Independent Science Panel (ISP)[2] (ISP 2002) and others had determined that few studies were available that tested whether habitat improvement actions increased numbers of juveniles migrating to the ocean or adults returning to the streams, although studies had shown that habitat projects could increase or shift the density of juvenile salmonids in local areas that were restored (Bayley 2002[3]; Roni et al. 2002).

Answering the aforementioned question presents a rigorous challenge for resource managers around the world (Palmer et al. 2005). Success depends on implementation of carefully developed and applied scientific designs and long-term, intensive monitoring of many actions over whole watersheds. Although habitat improvement projects occur in nearly all salmonid watersheds, validating the effectiveness of habitat improvement actions would be prohibitively expensive and difficult to do everywhere. With appropriate funding, design, and cooperation, however, it might be possible to test the effectiveness of habitat improvement in several demonstration watersheds.[4] Consequently, in June 2003, the Salmon Recovery Funding Board (SRFB), formed by the Legislature to help distribute moneys for salmon habitat projects and activities, began funding the Intensively Monitored Watershed program.

In April 2006, after nearly three years of development, the Governor's Salmon Recovery Office asked the ISP to review the IMW program[5] and to identify its technical strengths, shortcomings, and opportunities for improvement. The ISP has provided scientific

[1] Substitute Senate Bill (SSB) 5637.
[2] The Independent Science Panel was formed in 1998 by the Salmon Recovery Act (77.85.040 RCW).
[3] The Independent Science Panel commissioned a review of the scientific literature from Dr. Peter Bayley. Reference to and citation of specific data and sections of Dr. Bayley's report does not necessarily represent ISP endorsement or agreement with all report conclusions and recommendations.
[4] The Independent Science Panel discussed the economic and scientific trade-offs between large-scale regional monitoring programs and small-scale, intensive monitoring programs in ISP Report 2000-2, "Recommendations for Monitoring Salmon Recovery in Washington State."
[5] Memo to the Independent Science Panel from Bob Nichols, Senior Natural Resources Policy Advisor to Governor Gregoire, April 7, 2006.

guidance to the state on monitoring[6,7] and review of the comprehensive monitoring strategy and action plan as they were developed[8] and thus was well prepared to evaluate progress in monitoring. Specifically, we were asked to address the following questions:

1. *To what extent has the development of the IMW project plan drawn upon applicable scientific literature and background information? If you are aware of additional literature or information that should be considered, please identify it and clarify why.*

2. *To what extent does the plan suitably include the following elements:*
   a. *a conceptual framework*
   b. *monitoring objectives and questions*
   c. *testable hypotheses*
   d. *experimental design(s)*
   e. *sampling methods*
   f. *analytical methods, and*
   g. *data management?*

   Please clarify how well each element is supported and consistent with the scientific information that is available. Are some key components missing or inadequately addressed; are some components unneeded or inappropriate? Are there any noteworthy aspects that you think will pose implementation challenge? If so, please explain.

3. *Summarize how well you feel the IMW project will meet its objectives.*

4. *What are your most important recommendations for improvement of the IMW project?*

Throughout the Pacific Northwest, considerable monies are being spent on habitat improvement. Efforts to implement well-designed, coordinated, and effective monitoring for salmon and salmon habitat increasingly involves many local, state, tribal, and federal agencies and organizations. Interest in expanding the number of IMWs has also grown. Consequently, a review of the IMW program should be useful to these organizations, funding bodies such as the SRFB, and collaborative monitoring groups, such as the Governor's Forum on Monitoring[9], and the Pacific Northwest Aquatic Monitoring Partnership (PNAMP)[10].

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[6] Independent Science Panel (ISP). 2000a. Preliminary review of issues regarding the development of a statewide salmonid recovery monitoring program. ISP Technical Memorandum 2000-1.
[7] Independent Science Panel (ISP). 2000. Recommendations for monitoring salmon recovery in Washington State. ISP Report 2000-2.
[8] Complete ISP reviews and comments on the plan during its development are available at http://www.governor.wa.gov/gsro/science/documents.htm

[9] Governor's Forum on Monitoring website is http://www.iac.wa.gov/monitoring/default.htm
[10] The PNAMP website is www.pnamp.org

Approach

We focused our review of the IMW program on the draft *Study Plan for the Intensively Monitored Watershed Program* dated April 26, 2006 prepared by the IMW Scientific Oversight Committee and IMW Partners, and complementary materials and information provided by the committee during the course of our review. Supplementary material included 2004 and 2005 progress reports to the SRFB.[11] In addition the ISP received presentations from the IMW Scientific Oversight Committee at ISP meetings on April 26 and July 14, 2006.

Overview of the IMW Program

The purpose of the IMW program is to understand how salmon respond to habitat improvement by comparing the status of the salmon populations in watersheds undergoing improvement projects before and after the improvements occur and against similar, neighboring watersheds where improvements have not occurred. This review focuses on the IMW program in four watershed complexes in western Washington that is funded by the SRFB. Other efforts to establish IMWs are occurring elsewhere in the Pacific Northwest. Ultimately, with appropriate coordination these could lead to a network of IMWs increasing the overall usefulness of this kind of monitoring for making decisions about habitat improvement strategies. This appears to be the intent of the IMW coordination efforts of PNAMP, of which the SRFB-funded IMW program is a part. We hope our comments on the SRFB-funded IMW program will also be informative to those working on IMWs funded by others.

In western Washington, the SRFB-funded IMW program we reviewed has three components:

1) Evaluating the effects of freshwater habitat actions on production of juvenile coho salmon. This component focuses on three complexes of small watersheds flowing into the Strait of Juan de Fuca on the Olympic Peninsula, the Hood Canal, and the lower Columbia River. In each complex, habitat improvement activities target the major habitat factors that appear to limit salmonid production. The most abundant salmonids in these streams are coho salmon (*Oncorhynchus kisutch*), steelhead (anadromous *O. mykiss*), and cutthroat trout (*O. clarki*). In the Strait of Juan de Fuca complex, Deep Creek and East Twin River are the focus of major habitat improvement efforts and West Twin River is not. In the Hood Canal complex, Little Anderson, Big Beef, and Seabeck creeks are the focus of habitat improvement and Stavis Creek is not. In both complexes, coho salmon tend to be most abundant. In the lower Columbia River complex, habitat improvement actions are planned for Abernathy and Germany creeks, while reaches in Mill Creek will provide a reference with no improvement actions. Habitat in these streams tends to favor steelhead.

[11] The study plan and progress reports are available on the Salmon Recovery Funding Board website at http://www.iac.wa.gov/srfb/docs.htm

2) Evaluating the effects of estuary habitat improvement on growth and survival of juvenile Chinook salmon (*O. tshawytscha*). This component of the IMW program is located in the Skagit River estuary. Unlike the freshwater IMWs, no similar estuaries without habitat improvement exist in the Puget Sound for use as comparisons. Within the Skagit River estuary, however, staggered periods of habitat improvement on different reaches and deltaic subsystems, such as the North and South Fork, are intended to provide comparisons of effects before and after habitat improvement as well as between locations.

3) Developing a Pacific Northwest-wide classification intended to guide the application of IMW results to other watersheds. This component of the IMW program builds on the assumption that watersheds that are most similar for the natural variables thought to affect salmon production—such as climate, watershed topology, vegetation, stream gradient, and land use—are most likely to respond similarly to habitat improvement. Using a variety of algorithms, this component of the project intends to identify which watersheds are most similar to the IMW watersheds and those that are most different.

Findings

Based on our current and past reviews of Washington's monitoring and knowledge of other monitoring efforts, we conclude that the SRFB-funded IMW program is designed as a comprehensive watershed scale effort that could represent the beginning of a state-of-the-art intensive monitoring program of salmon habitat improvement. It is one of only a few studies to address this issue (e.g., Ward et al. 2002; 2003; 2006). The strengths of the project include a solid scientific conceptual framework, a basically robust study design, and a well-qualified team of scientists. Weaknesses include (1) potential lack of coordination between how treatments (i.e., the habitat improvement actions) are selected and funded as it affects the implementation of the IMW statistical design, sampling, and analysis; (2) uncertainty about whether the IMW program will continue long enough to reap the benefits of the experimental design; and (3) the limitation of opportunities for selecting optimal study watersheds or complexes. In addition, the study plan lacked detailed descriptions of the procedures and analytical designs for the specific study components or complexes. The draft study plan adequately provides the basic scientific description of the project but we noted a number of situations where more detail would strengthen it.

Responses to Assigned Questions

Question 1: *To what extent has the development of the IMW project plan drawn upon applicable scientific literature and background information? If you are aware of additional literature or information that should be considered, please identify it and clarify why.*

The literature on monitoring and stream habitat improvement is vast and continues to expand (e.g., Roni 2005; Jenkinson et al. 2006). The study plan includes much of the essential literature base in the 51 references listed. From the text it is clear that the plan is based upon the latest concepts in ecological monitoring. Examples from the few other studies examining fish responses at the watershed scale (e.g., Ward et al. 2002; 2003; 2006), that have been able to detect a response by fish populations in altered habitat, would add support to this plan. The literature and background information provided an in-depth assessment of monitoring methodologies and descriptions of conditions at the various study complexes. However, the plan would benefit by including primary scientific references and discussion of **B**efore-**A**fter/**C**ontrol-**I**mpact (BACI) experimental designs, and their application in most of the four watersheds (see also our comments under Question 2, Experimental Design). The basic BACI design is reported by (Green 1979) and has subsequently been modified in various forms (e.g., Stewart-Oaten et al. 1986; Osenberg et al. 1994; Underwood 1996; Korman and Higgins 1997; Hewitt et al. 2001; Stewart-Oaten and Bence 2001; Bradford et al. 2005) each of which has its adherents and critics. These references contain thorough discussions of the strengths, weaknesses, and misinterpretations of the BACI design. We noted several problems and shortcomings with applying the classic BACI approach at individual IMW study complex sites (see discussion below). Our meetings with the IMW Oversight Committee confirmed that they are also aware of the limitations. We suggest that the plan be revised to include more details on the individual BACI design <u>for each of the study complexes</u> and appropriate references supporting its strengths and weaknesses, and how the weaknesses can be addressed.

The plan could also be improved by including discussion of how monitoring signals may be detectable by linking scales of different magnitudes (see Lowe et al. 2006). This may have direct application to the study design in the Skagit River estuary, which intends to "use different monitoring designs at different spatial scales to evaluate the effects." Scale linkages may also have ramifications for how the data from the BACI design is analyzed, for example, using trends in sites-specific population trajectories versus analysis-of-variance (ANOVA) type analyses.

The plan includes very little discussion or reference to scientific literature in support of the landscape classification component of the program. It could use support from the scientific literature in three different areas: (1) identifying the key determinants of physical and biological processes in watersheds and the algorithms that will be used to quantify the impact of land-use practices, (2) describing the merits of different clustering algorithms, and (3) examples of how classification approaches have been used and validated to generalize beyond single studies analogous to what is proposed here.

Considerable bodies of literature exist on the first two areas and the investigators appear to be familiar with them. Literature in support of area 3 is very limited. Could the plan, for example, provide support for the proposed approach using examples of watershed or ecoregional classifications that correspond to fish life history differences or other measures of performance?

Question 2: *To what extent does the plan suitably include the following elements?*

Conceptual Framework

The scientific fundamentals of the draft study plan are on target. The basic premise of the conceptual framework is that to be able to detect the relationship between habitat improvement and fish production it is necessary to conduct improvement efforts at the appropriate spatial scale and intensity so that the all freshwater life stages could benefit, and include monitoring that is statistically powerful enough to detect whether the benefits occurred or not. The basic study units are at the geographic scale of a watershed where the number and trends in juvenile fish migrating to the ocean (smolts) would be an indicator of changes in freshwater productivity. Smaller sampling units can be nested in a spatially hierarchical scheme to detect effectiveness and biological responses (e.g., fry, fingerling, and pre-smolt abundance) at other geographic scales (e.g., reach or tributary). BACI-type designs would be used to detect changes and the restoration designs would facilitate the detection of responses, if any, to the habitat improvement.

The premise addresses the fundamental complexity and issues of scale and design that have made it difficult to empirically demonstrate whether or not past stream habitat improvements have been successful or not at increasing fish populations despite considerable expenditures on such actions. For example, past habitat improvement efforts were often conducted on small, often fragmented patches of stream reaches. Statistical power of the monitoring, if applied, was insufficient to detect population changes because sampling was not designed to capture the spatial and temporal variation in the fish environments; any effect of habitat improvement actions may have been masked by changes in climate, ocean conditions, or population density.

An issue that should be better addressed in a revision of the study plan is how the current approach can distinguish between the uncertainty arising from the choice and sequence of treatments (i.e., the habitat improvement strategy) and the uncertainty associated with the habitat improvement techniques themselves. The general approach to choosing the habitat improvement strategies seems to be based on identifying techniques that address known or suspected limiting factors to salmon production in the watershed. Although the study plan describes the status of habitat in the study watersheds, the reliability of the basis for these status assessments of limiting factors is unknown and the plan does not describe the protocols for reaching these conclusions or the confidence of the investigators in the assessments. Consequently, failure to detect a benefit of habitat improvement could be due to either a poor understanding of habitat forming processes limiting salmonid production or to the effectiveness of the techniques themselves.

Another source of uncertainty that should be addressed in a revised study plan is procedural problems in implementing the habitat improvement projects (i.e., study treatments and controls). Though procedural problems can be considered non-technical in nature, they fundamentally relate to the integrity of experimental designs and scientific certainty, and thus can be key factors affecting success. Natural resource monitoring often fails because of procedural problems as well as scientific design issues. For example, Reid (2001) examined 30 flawed monitoring projects and found that procedural problems occurred in 50% of them. These included (1) poorly trained or unmotivated field crews (37%), delays in analyzing data (27%), absence of collateral information to interpret results (20%), technological failures (17%), lack of continuity due to personnel changes (13%), lack of institutional commitment (10%), and protocol changes that affected comparability of the results (7%). A procedural flaw that Reid (2001) did not identify, but that may occur in some of these IMW programs, is that a different process or group of people is responsible for selecting the treatments (i.e., the habitat improvement actions) than is responsible for the IMW statistical design, sampling, and analysis. Many monitoring plans are fundamentally based on the template of a research plan for small, controlled experiments where procedural problems are assumed to be minimal and consequently these problems are not addressed. The increased complexity and logistical difficulties of long-term monitoring programs in natural systems greatly increases the chance of procedural problems. Although these might not be major issues for the IMW program now, we recommend that the study plan address how these potential problems will be controlled as some are certain to occur in the long run.

It needs to be clear that the IMW program is part of an overall attempt to recover depleted populations of salmon in Washington. In addition to describing the scientific context and framework for the plan, the study plan should describe how the IMW program fits with salmon recovery strategies and other monitoring programs beyond the obvious common source of funding by the SRFB. The plan could incorporate better explanations of the link between the IMW program and salmon recovery planning and habitat improvement goals in local watersheds across the salmon recovery regions at least in western Washington. What is the connection between monitoring and implementation of local watershed recovery plans and IMWs? Although this study plan focuses on the SRFB need to evaluate habitat improvement projects, it appears that IMWs could also provide opportunities to test the effectiveness of other recovery strategies, such as habitat protection through regulatory mechanisms, acquisitions, and water management. This could expand the value of IMWs to many more watersheds and agencies.

Finally, although our review is limited to the western Washington IMWs, it would also be useful for the study plan to discuss the context and relationships of the IMW program to other IMWs in Washington (i.e., the larger scale river basin efforts in the Wenatchee and Entiat river basins) and regional efforts such as the Pacific Northwest Aquatic Monitoring Partnership[12]. Ultimately, the power of analyses from IMWs funded by different entities to affirm or influence changes in salmon habitat improvement approaches more

[12] See "Establishing a network of intensively monitored watersheds in the Pacific Northwest" PNAMP 2005. (http://www.pnamp.org/web/workgroups/PEM/meetings/2005_0830/2005_0405IMWPlan.doc)

generally, will likely depend on examination of similar (or different) results from a much broader network of IMWs where habitat improvement actions are replicated in different streams and habitats.

Monitoring Objectives, Questions, and Testable Hypotheses

The draft study plan describes general monitoring objectives and questions for the different IMW complexes in general terms only. We strongly recommend that all monitoring objectives be rewritten as hypotheses amenable to testing, for each IMW complex and for all levels of study scale including watershed, sub-watershed and reach.

The monitoring objectives and questions vary for the three IMW program components and among individual freshwater study complexes. The objectives for some IMW complexes are well-developed whereas others are not. In some cases, it appears that the watershed restoration objectives, which are an integral part of developing specific monitoring objectives and designs, have not yet been finalized. Finalizing these is critical to be able to proceed with a well-designed experimental approach and monitoring program. As mentioned earlier, when different processes or groups are involved in developing habitat improvement objectives than are involved in the design and implementation of monitoring, lack of effective coordination can become a major and even fatal, procedural flaw.

Monitoring Objectives for the Freshwater Habitat Complexes

The general monitoring objectives for the freshwater watershed complexes are (1) to determine whether freshwater habitat improvement can effect a change in number or productivity of coho salmon, steelhead and cutthroat trout out-migrants, and (2) if a change is detected, to determine what system features or processes influenced by the habitat improvement caused the increased production. These monitoring objectives seem consistent with the linkages between habitat quantity, habitat quality, and productivity at salmonid life stages. We agree with the assumption of the draft study plan that focusing the objectives on these species in small watersheds increases the tractability of the IMW program. These species have extended freshwater rearing-stages, which make them more responsive to changes in freshwater habitat. Focusing on small watersheds means that study designs can be based on improving a much larger proportion of the impaired habitat than in very large watersheds. For guiding recovery strategies, qualitatively similar results should be expected from employing rigorous watershed assessments and treatments with other species and in watersheds of other sizes, although precisely predicting the magnitude of these changes will not be possible for the SRFB-funded program alone.

The objectives depend on the fact that reduced quality and quantity of habitat results in fewer surviving offspring per adult spawner or deposited egg. Actual effects depend on the character of the insult and may be evident in any or all of the relations between parr produced per egg, fingerlings per parr, or smolts/adults per fingerling, depending on the factors affecting natural production. Successful habitat improvement is expected to produce more outmigrating juveniles or smolts at any spawner (egg) density. Monitoring

different freshwater life-stages will determine whether the identified limiting factors are correct, whether the selected habitat improvement actions were successful, and will help to account for the effect of fish population density on the outcome in terms of fish response.

We suggest two specific changes to improve objectives. As currently written, objective 2 will not be addressed unless objective 1 is met. We suggest modifying objective 2 to read: "What system features or processes influenced by the habitat improvements caused the increased production or the lack thereof." The information gleaned in this effort would be valuable to explain why a change in production of outmigrants did *not* occur. Because the objectives are not time-specific, we also recommend consideration of a third objective: "To determine if and how beneficial effects of habitat improvement on fish production are maintained over time."

Beyond the general monitoring objectives, the specific objectives for the Strait of Juan de Fuca, Hood Canal, and lower Columbia River complexes are not equally well-developed. For example, the plan identifies four specific objectives and questions for the Strait of Juan de Fuca complex dealing with effects of individual habitat improvement activities and channel conditions on the survival, growth and movement of fish. Likewise, site-specific objectives are described for the Hood Canal watershed complex regarding relations between flow, sediment, temperature and smolt yield. These objectives are testable but need to be clearly identified as hypotheses. The objectives for the lower Columbia River complex in contrast, need more specificity.

Monitoring Objectives for the Estuarine Component

The objective of the Chinook salmon estuary component is to understand changes in population characteristics (e.g., abundance, productivity, survival and life history diversity) of wild Chinook salmon in response to reconnection and habitat improvement of estuarine habitat in the Skagit River estuary. A large set of supporting information and past studies provides a strong knowledge base for this effort. Each component of the population characteristic assessments and the individual habitat improvement assessments needs to be developed into a clear and testable hypothesis statement.

Objectives for Landscape Classification Component

We do not feel it will be possible to develop a reliable empirical model to extrapolate from the results of just the SRFB-funded IMW complexes directly to other watersheds across the state because of the small number of watersheds being studied, and the breadth of diversity in salmon habitats and watersheds that exist. The third component of the IMW effort addresses this problem using a landscape classification approach, based on the assumption that watersheds with similar characteristics should respond similarly to habitat improvement. Consequently, two objectives are presented for this effort. The initial objective is to classify and group watersheds with similar biophysical and anthropogenic characteristics in relation to the IMW study watersheds. The plan clearly identifies tasks and steps to reach this objective. The revised plan should more clearly

describe how information from SRFB-funded IMWs will be used in the classification, and how information from IMWs funded by others will be utilized.

We feel the initial objective is a logical approach for stratifying watersheds. It may provide a useful tool for extrapolating IMW study information and for habitat improvement planning, if it can be validated. It will not be a testable hypothesis on its own until an attempt is made to link the classification to salmonid production in a way that can be tested. This second phase of the landscape classification effort needs to be clearly articulated in a revised study plan.

Experimental Designs

The basic experimental design used in the draft IMW study plan is the **B**efore-**A**fter/**C**ontrol-**I**mpact (BACI) experimental design. This is a general category of experimental design that has been used for many years for evaluating environmental impacts of watershed management activities and is very appropriate (Roni et al. 2005), especially when used at several different spatial scales as planned in the IMW studies.

An important aspect of experimental design development is an understanding of the statistical power to detect changes or trends in variables of interest. The draft study plan does not include analyses of statistical power. Power analyses should be included in the study plan. We would expect the results of these analyses to be able to support the choice of the magnitude of habitat improvement efforts being used as treatments, the intensity of sampling needed, and the length of time before a response might be detected (especially in watersheds that may have only a few years of baseline data when the project was initiated). The plan provides few details on these aspects, although these are critically important for the scientific success of the program and to communicate to decision makers what might be expected from the program, including cost considerations.

As noted earlier (under Question 2), an issue that is not well addressed in the conceptual framework and consequently the experimental design(s) is how the current approach can distinguish between the uncertainty arising from the choice and sequence of treatments (i.e., the habitat improvement strategy) and the uncertainty associated with the habitat rehabilitation techniques themselves. Although the study plan describes the status of habitat in the study watersheds, the reliability of these assessments for choosing habitat improvement strategies is unknown. The plan does not describe the protocols for how these habitat improvement actions were prioritized and chosen among the suites of alternatives or the confidence that the investigators have in the assessments that led to them. As these are essentially choices of treatments, the protocols for minimizing this uncertainty should be described in the plan as part of the experimental design(s).

Freshwater IMW Complex Experimental Designs

The study plan should detail how the BACI design will actually be applied in each of the IMW complexes. In many real world situations, all the conditions of a classic BACI design may not be met (see references provided under Question 1), and that appears to apply here. Furthermore, the plan does not explain how data from the designs might be

analyzed to address current weaknesses or how and why the designs might appropriately change over time.

For example, the **B**efore and **C**ontrol components are critical to the integrity and use of this design. The control (or reference) and to-be-treated study sites should be reasonably similar and the period **B**efore the treatment should long enough that the pre-treatment (or improvement) response of interest is well-defined and closely correlated between both areas. In addition, there should be no impacts beyond baseline conditions on any study area during the **B**efore period and no impacts beyond baseline conditions on the **C**ontrol area throughout the life of the study. To illustrate, outmigrant production of coho salmon, steelhead, and cutthroat trout would be the response of interest in the case of the watershed scale studies in the freshwater study complexes. Data collected during the **B**efore period should make it possible to predict what the outmigrant production would have been without habitat improvement thus providing a basis for determining the statistical significance of the measured production with habitat improvement. It is not clear how well this condition is met for the different study complexes, especially in the case of the Strait of Juan de Fuca complex where no pre-treatment productivity can be described. Consequently, it may be necessary there to use some other sort of experimental design such as time trend analysis (an approach that would require assumptions regarding the rapidity of response by the population) or apply additional treatments over time after existing conditions are properly calibrated. In addition, more discussion is needed about how and why the references sites were selected and how effective they are expected to be at each study complex and at all study scales.

The **A**fter and **I**mpact components of the BACI design are also critically important. Ideally, the impact involves only that planned for the study and its application takes place within a short period of time to minimize time trends in effects. Problems in this regard are apparent in the IMW freshwater watershed complexes where watershed disturbances other than habitat improvement can occur and habitat improvement measures are applied over several years. There is little discussion about how this will be treated in the study plan. This is especially important in the Hood Canal watershed complex where urbanization is occurring to varying degrees. Changes in the amount of impervious area due to urbanization of only a few percent can have profound effects on aquatic habitat (e.g., Booth and Jackson 1997; May et al. 1997; Konrad and Booth 2002) making it difficult to isolate (or even negating) the effects of habitat improvement efforts on salmon from those of unwanted land uses at the watershed scale. This is especially true if the unwanted disturbances are not applied uniformly in all basins, which is likely to be the case. A multi-scale design (i.e., reach, sub-watershed, and watershed) may help account for some of the effects of unwanted land uses at least at the reach and sub-watershed levels. Given the importance of unwanted land-use effects the amount, location, and type of land use activities existing prior to the study and occurring throughout the study need to be fully documented (and quantified) for all watersheds in each IMW complex. As noted in references we suggested for Question 1, this information can then be used as covariates to account for variation as part of analyses.

Skagit River Estuary Experimental Design

As noted earlier, no appropriate control (reference) estuary exists for the Skagit River estuary component of the draft study plan. Consequently, it is appropriate that at the estuary scale the design is basically a hierarchical Before-After experimental design. The study plan notes its limitations and describes alternative designs for addressing these limitations. The BACI study design is used at the reach and deltaic subsystem scale. In addition, the Skagit study employs a sophisticated staircase design (Walters et al. 1988; Roni 2005) , which evaluates the sequential treatment of control and impact reaches in the estuary over time. This kind of approach may be useful for other IMW monitoring problems that are not amenable to the classic BACI design and its permutations.

Landscape Classification Design

The draft study plan does a good job of providing a description of the methodology used for the analysis of the initial objective of the landscape classification component , which is simply to develop the classification. However, the plan should include an experimental design component to validate whether the results of the IMW programs can be generalized to watersheds without intensive monitoring using the classification system.

Sampling Methods

The draft study plan and additional materials do a good job of describing the variables to be monitored. These should provide appropriate information on the quality and quantity of the habitat and the response of the fish. Sampling methods are well described in the study plan for most study complexes and study scales. However, it is important to remember that sampling to detect a change in the multifaceted conditions associated with freshwater and estuarine systems is difficult at best (Korman and Higgins 1997). It is possible that the natural variation in population parameters will be so great that detection of the changes required to test hypotheses or to meet other goals and objectives is not a reasonable expectation. As noted earlier, we strongly recommend that estimates of the statistical power be developed and included in the study plan for guiding the treatment and sampling efforts.

The draft study plan does not address the need for standardized sampling protocols or variables. In several sites, for example, the investigators intend to use different population survey techniques, but it is not clear how the investigators will detect and address differences related to the use of different techniques. In addition to the sampling within IMW complexes, standardized sampling protocols, variables, and techniques to adjust for any differences will be important in conducting future meta-analyses. We recommend that the study plan include an analysis of the need for standardization and how it will be accomplished, for SRFB-funded IMWs, and in consideration of other IMWs in Washington that are funded by others and the coordination efforts of PNAMP.

Analytical Methods

For the most part, details of proposed analytical methods are not provided in the draft study plan. Most of the analyses that are described rely on classical statistical techniques.

This is reasonable given that specific analytical methods derive directly from the experimental designs used as well as the nature of the data collected and its statistical power. That said, general methods of analysis should be anticipated from the experimental designs and data should be analyzed to clarify statistical power as it develops to provide confidence that successful tests are possible. Likewise, Bayesian statistical analyses, which are often overlooked in monitoring but may be useful for detecting change and expressing the results for decision-making (e.g., Reckhow 1990; Ver Hoef 1996; Ver Hoef and Frost 2003), should be considered.

Limitations in experimental designs as described above must be assessed and analytical methods adjusted accordingly. For example, effects of urbanization on streams in the Hood Canal complex need to be evaluated and accounted for using covariates designed to assess effects of urbanization over time. There are several figures presented in the draft study plan illustrating apparent cause-and-effect relationships but no supporting statistical information is presented.

A revision of the draft study plan should begin to address the potential for meta-analyses comparing results across individual SRFB-funded IMW projects or IMW projects funded by others elsewhere in Washington and across the Pacific Northwest. Such analyses should increase the power to draw conclusions about the effectiveness of habitat improvement projects, IMW programs, and fish population responses (e.g., Bender et al. 1998; Bennett and Adams 2004; Boyce et al. 2005; Cote et al. 2005). We feel the growing opportunities to coordinate monitoring designs and objectives, standardize sampling methods and monitoring variables, and share data across the state and beyond, including programs such as the Pacific Northwest Aquatic Monitoring Partnership, are very exciting and have potential to create synergy and increase the efficiency and utility of all IMW programs. We recommend strong consideration of both the statistical options for how such analyses might be done and the organizational structures needed to support them.

Data Management

The draft study plan contains little to no information on approaches to management of the diverse and complicated array of IMW data management issues in general, or for individual program components. Data management—including quality control, sharing/accessibility, and transparency—is critical to the success of individual components and meta-analyses across IMWs, both within Washington, and across the Pacific Northwest. At a minimum, the study plan should include information to address the following questions: What metadata and metadata standards are being used? Are data being collected using standardized protocols, and if not, what methods will be used to adjust for the differences? How are timely data collection, reduction and analysis assured? What data quality assurance controls (QA-QC) will be used? Who does timely data analysis? How and when will basic and compiled information or analyses be reported and made available to interested parties? How are data, results, and analyses coordinated and integrated among the different IMW complexes (i.e., SRFB-funded, statewide, Pacific Northwest)? Since adaptive management is as important in conducting watershed scale studies of this type as it is in dealing with land management issues, what

is the adaptive management framework within which the results of the study plan will be fed, and how will adaptive management decisions be made?

Question 3: *How well will the IMW project meet its objectives?*

As with any study, how well the individual objectives are met in the IMW studies depends on a number of factors. These are (1) identification of goals and objectives, including scale (watershed vs. sub-watershed or reach level studies), (2) choice of appropriate statistical designs and models, including the desired (or acceptable) level of precision, statistical power, and effects of uncontrolled factors (floods, wildfire, etc.), (3) the choice of variables and indicators, (4) monitoring and sampling protocols, (5) quality assurance of the data, (6) coordination and management of the data, (7) adequate funding and resources, and (8) analysis and integration of the results into decision making (ISP 2000). The strengths and weaknesses of the draft study plan in these areas are noted above. Unfortunately, the plan does not provide information about all of these factors. Therefore, although we indicated earlier in this review that we feel the IMW effort is comprehensive, has made much progress, and could represent the beginning of a state-of-the-art IMW program for salmon habitat improvement, at this time we cannot provide a definitive answer to this question.

Overall, the success of the program will depend on building on the strengths of the work in different watershed complexes and the effectiveness in addressing the weaknesses. The strengths of the program include a solid scientific conceptual framework, basically robust study design(s), and a well-qualified team of scientists. Generally, other things being equal, we would expect the likelihood of successfully meeting objectives (and extrapolating results) to be inversely proportional to the spatial scale of the study (i.e., greater for reach scale studies than watershed scale studies). Consequently, although the program focuses on small watersheds or portions of a watershed, such as the estuary, this is appropriate at this stage of IMW monitoring, and well complements IMW work in larger watersheds that is being funded and conducted by others.

In general, there are several overall weaknesses in the draft study plan that we have discussed above that diminish the likelihood of success. In addition, there are a number of structural elements that the SRFB and IMW program need to address for success. First, a very serious weakness exists to the extent that selection of treatments (i.e., the habitat improvement projects or actions) is disconnected from the needed statistical design, sampling, and analysis for IMW program success. From a scientific perspective this is a potential procedural (maybe even fatal) flaw in the overall approach to implementation of the experimental designs. It is crucial that the habitat improvement actions be appropriately chosen and with impacts large enough and that sufficient monitoring be in place to detect a response, if one occurs. If the choice of habitat improvement projects and funding that implements them are not appropriate and not well-coordinated with the monitoring effort (projects meet treatment and control design needs), affected IMWs will be unable to achieve their objectives.

In addition, it is not clear how the rigorous technical and administrative demands of the program are structured to ensure objectives can be met. The technical and practical challenges of IMW work are considerable, not just in terms of the relationships of habitat improvement projects in support of the IMW experimental designs, but also for management of the IMW program in general. What is the nature of the IMW Oversight Committee and what are the responsibilities of it and its members? Who has responsibility for implementation of the various kinds of monitoring needed (e.g., fish populations, changes in land management, and habitat modifications [for specific treatments, and background or baseline changes])? Who handles and archives the data? Who does the analyses and what review and comment processes will be used? We recommend review and clarification of organizational structure(s) that are commensurate with the rigorous IMW design, implementation, analysis, and reporting challenges.

Similarly, the lack of power analysis weakens the likelihood of success of the plan. We expect the results of such analyses would strengthen confidence in the choice of experimental design, level of effort needed for treatments, the intensity of sampling needed, and the length of time before a response might be detected.

Finally, although the draft study plan did not address the magnitude and longevity of the funding for the IMW projects, uncertainty in prioritizing funding for IMW monitoring and needed habitat improvement projects is a weakness that could affect how well the program meets its objectives. Long-term monitoring and funding is critical for the success of these kinds of efforts (Reeve et al. 2006). As noted by the ISP (2002), the number of long-term studies continues to decrease. Without long-term monitoring it is difficult to detect trends in populations and the link between habitat changes and juvenile and adult abundance. Although the IMW complexes were chosen based in part on the availability of good historical data on juvenile and adult fish abundance, for some species in some locations such as the Strait of Juan de Fuca and parts of the lower Columbia complexes, the lack of pre-existing long-term data sets is an obvious weakness. Potentially, this weakness can be addressed over time by continuing funding for habitat improvement and monitoring, and conducting and incorporating power analysis into ongoing experimental design development, and refinement as necessary.

Question 4: *What are your most important recommendations for improvement of the IMW project?*

1. Develop specific, detailed study plans for each study component and IMW complex. The focus should be on providing the detail to support the statistical rigor needed to achieve program objectives. State all study objectives as concise and testable hypotheses. Identify the major sources of uncertainty and variation. Conduct power analyses upon which to base sampling schemes, and describe sensitivity analyses for analyses based on models or structural equations that can ascribe study results in terms of explicit timeframes and checkpoints for review.

2. Clarify what to expect from generalizing across IMWs. It is important to recognize that the results of the IMW studies (especially those at the basin scale) can be

extremely difficult to generalize and extrapolate. It is important to describe what to expect from such extrapolations (and what not to expect). It will not be possible to use the landscape stratification effort for this purpose without proper validation. With or without such validation, the most important role of IMWs may be to provide a series of case studies about which generalizations may be qualitatively applied to other areas. Developing meta-analyses by coupling the results of these IMW projects with other IMW efforts in the Pacific Northwest should provide much more data and power to test the efficacy of the landscape stratification for more quantitative extrapolation purposes. In addition, other techniques for extrapolating results should be considered such as regional regression techniques, meta-analysis, and Bayesian analyses that could incorporate information and uncertainty from other studies.

3. Develop coordination mechanisms to ensure that habitat improvement actions identified within IMW watershed complexes are appropriately chosen and implemented at a large enough scale to be able to detect a response if it occurs, consistent with the experimental design.

4. Support the collaborations that already exist between this SRFB-funded IMW project and others funded by other agencies in the Pacific Northwest and expand this collaboration.

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